Quieting a switch-mode power supply

Drew Diamond VK3XU

A number of radio and electronics suppliers offer a neat little generic low-priced, switch-mode power supply unit (SMPSU), whose output is nominally 13.8 V at up to 10 or 15 A. SMPSUs (SMs) are smaller, lighter, cheaper, cooler and more efficient than conventional transformer type supplies. Unfortunately, they also have a reputation for producing radio noise.

A switch-mode PSU is essentially a 20 - 200 kHz square-wave power oscillator which, if not adequately filtered, incidentally injects rich harmonic energy back into the mains supply, and/or into the load. The H-field (leaked magnetic flux) surrounding the PSU may also directly affect nearby receiving equipment. A technical writer once quipped that SMs were invented by an accountant (another called them "an invention of the Devil").

My sample model has a minimal amount of filtering on the mains (or line) side, and in the positive output lead only of the PSU, perhaps sufficient to allow an ordinary broadcast receiver in the same house to hear Radio National. But we amateurs routinely listen for signals right down in the microvolt region, which makes SMs a less than ideal device for powering radio equipment in small-signal work.

Another rather unfortunate characteristic of some SMs is their behaviour when the current limit is reached - they shut down completely. The user must wait some seconds before re-applying primary power. An internal fan is included which operates automatically to cool the internal power devices. So, acoustic fan noise is another issue.

Notwithstanding these shortcomings, it is possible to greatly reduce the amount of conducted radio noise by fitting additional filtering in the mains input side, and in the positive and negative DC output leads.

Mains input filter

There are usually two components contained in the noise emanating from the mains power connector. They are 'normal-mode' (i.e. a noise voltage occurring between the active and neutral conductors), and 'common-mode' (noise voltage of about equal phase and amplitude on both conductors with respect to earth ground). Fortunately, the job of reducing both kinds of noise may be tackled in this instance by simply adding a ready-made mains or 'EMC' filter.

The series inductive element universally used within EMC filters is a clever device called a 'current compensated inductor' (Reference 1, Chapter 9, and Reference 2, page 28.11), in which a ferrite toroidal core has two identical contra-wound coils, so the net magnetic flux created in the core by the line (or load) current will be very small. It is thus possible to use a core without an air gap, yet maintain a high impedance to noise currents without saturation effects due to the line (or load) current.

The EMC filter may be accommodated in a plastic 'jiffy' box measuring 130 x 67 x 44 mm, pictured in Photo 1. A useful amount of additional common-mode rejection may be had by winding the active (line) and neutral wires upon an LO1238 toroidal core as follows:

Remove the outer sheath from about 600 mm of an ordinary IEC power cord (discarding the usual 3-pin mains plug). The job is eased by removing only small sections of perhaps 100 mm of the sheath at a time. Wind the brown (Line) and blue (Neutral) wires side by side together upon the toroidal core, about 10 loops, which are connected to the (L)ine and (N)eutral tags of the EMC filter. The earth (green-yellow) wire, cut to an appropriate length, by-passes the toroid and connects directly to the centre earth pin of the filter. Remember to either tie a knot in the cord, or attach a plastic cable-tie to prevent the cord from being pulled out. The toroidal core may be fixed to the bottom of the box with a blob of hot-melt glue (silicone would also serve).

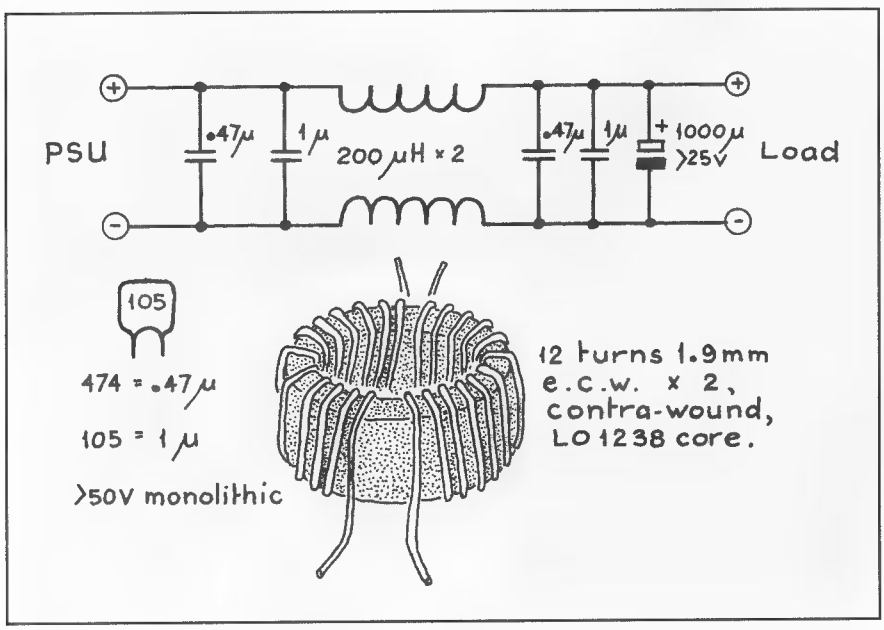


Fig 1 – Circuit diagram of the DC output circuit

DC output filter

Residual harmonic energy upon the DC side may be substantially removed by passing both the positive and negative output leads through a compensated series inductor, which acts in the same manner as described above for the line filter's inductor. The 200 µH coils (Figure 1) are wound upon an LO1238 toroidal ferrite core in opposite directions, so there is no net magnetic flux due to direct current flowing through the coils. Core saturation, or reduced effective inductance, is thus avoided.

The circuit is shown in Figure 1. The 0.47 µF and 1.0 µF capacitors should be low-inductance monolithic types, 50 V working. These, and the toroidal coil, may be accommodated upon a 40 mm x 70 mm rectangle of double-sided circuit board, pictured in Photo 2. The 'lands' may be formed by equally dividing the rectangle top and bottom with a hack-saw cut, down and across.

Measure the exact spacing of your SMPSU's terminals and drill holes in the board accordingly. A similar pair of holes at the opposite end is made to take binding-post terminals to suit your equipment set-up (19 mm [0.75"] spacing is suggested, as this fits ready-made twin-banana type plugs).

It is vital that upper and lower lands be connected together. Drill a 1.5 mm hole in four places (avoiding terminals) so that #16 B & S tinned Cu wire (Cu is the shorthand chemical symbol for copper) may be passed through and soldered each side.

For the coil(s), wind on 12 turns of 1.9 mm enamelled Cu wire for each leg of the coil. Note that they must wind in opposite directions, as depicted in Figure 1.

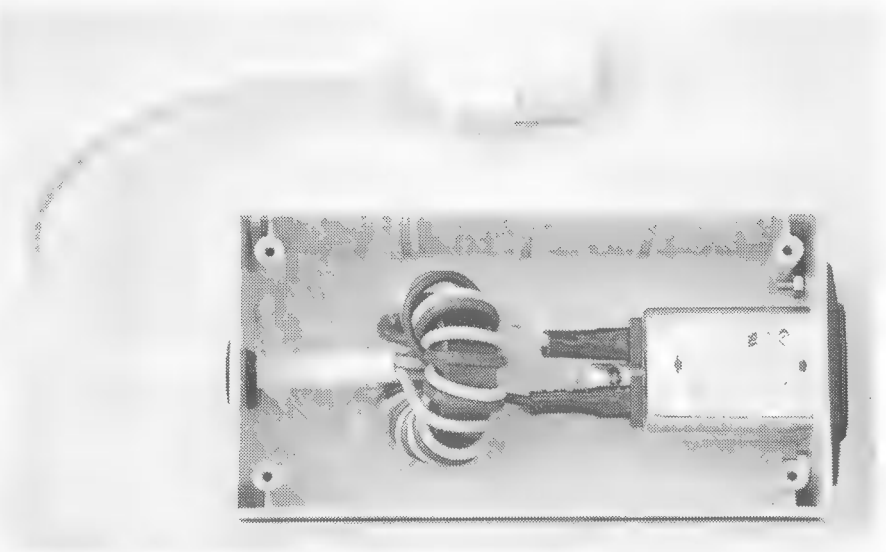


Photo 1 – Additional mains filter, inside view.

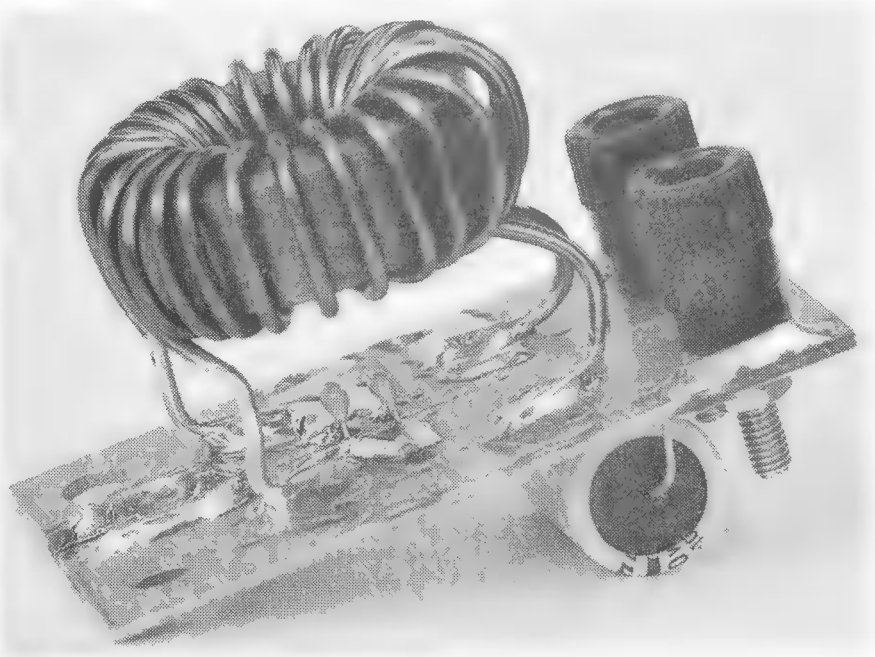


Photo 2 – DC filter

Reduced fan noise

For the sample model, when current demand is above about 5 A, the fan will automatically cut in, and thus cycle on and off according to demand. If this irritates you (and the idea of voiding the warranty is not a problem), the following modification is suggested by Robert Broomhead, VK3KRB (see the separate article in this issue, on page 12).

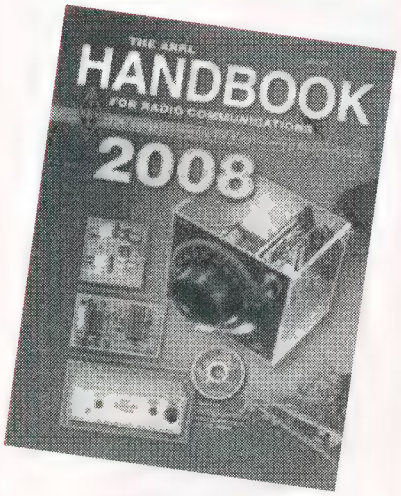
Locate the 45 degree C thermal cut-out switch, which is mounted upon the heatsink immediately next to the fan. Carefully solder an 82 or 100 ohm 1 W resistor across the tags of the cut-out, taking care that sufficient clearance exists between the resistor and the heatsink, and also the cover (when replaced).

With this addition, only 6 V is applied continuously to the fan motor, and so it quietly ticks over, making much less noise, whilst very adequately cooling the power devices such that the thermal switch only needs to cut in and apply full voltage to the motor during heavy demand periods.

Before and after

It is suggested that your transceiver (or other equipment) be first operated from the PSU without additional filtering fitted. Carefully note the strength of any rough, wobbly noise signals created by the PSU. When the mains and DC filters are installed (Photo 3), it should be found that these are considerably reduced in strength, or eliminated, particularly if your HF antenna has a matched coax, or truly balanced feed-line.

Amateur Radio Bookshop



Discounts for members

Download our catalogue at

http://www.wia.org.au

Amateur Radio Bookshop
PO BOX 3084
EAST BLAXLAND
NSW 2774
Office: WIA National Office
Tel 03 9528-5962
Fax 03 9523-8191
bookshop@wia.org.au

ARRL – RSGB publications
books
magazines
CDROMs - DVDs

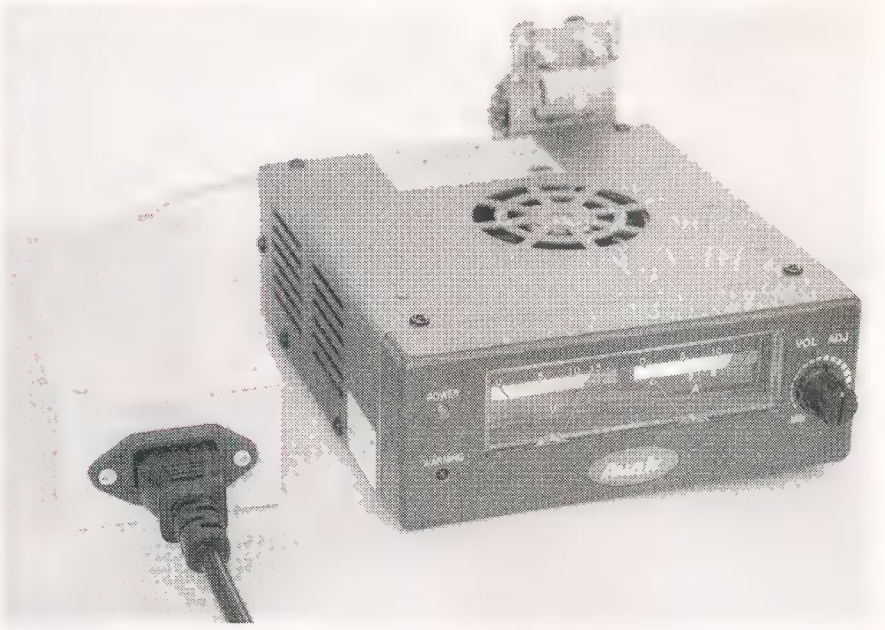


Photo 3 – Mains and DC filters installed.

Conclusion

Although SMPSUs are not ideal (in this writer's opinion) for use in a small-signal radio environment, it is highly likely that their attractive price and small size will cause many amateurs to use them to power transceivers and other equipment designed to operate from a nominal 13.8 V DC supply.

Tests upon a typical PSU indicate that noise conducted from the mains and DC side may be simply and cheaply reduced to an acceptable level, thus allowing small-signal work to occur.

Parts

It happens that most of the components for the prototype filters were purchased from my local Jaycar shop, including jiffy box, HB6023; EMC filter, MS4003; toroidal cores (packet of 2), LO1238; and capacitors. Similar suitable parts are also available from our other suppliers, including Altronics, DSE and Semtronics.

References and Further Reading

1. *Switched-mode Power Supplies In Practice*; O Kilgenstein. John Wiley & Sons.
2. *Radio Communication Handbook*; 8th edition, RSGB.

Photos: Karlen Dockrey

ar

John Moyle Memorial Field Day

15 & 16 March